MODELLING FOR PREDICTION AND OPTIMIZATION OF MECHANICAL RESPONSE OF UNEQUAL THICKNESS STEEL SHEET RESISTANCE SPOT WELDS IN TENSILE-SHEAR LOADING CONDITION

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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor Of Mechanical Engineering (Design and Innovation)"

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Date: ……………………………

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledge".

Signature: ………………………………..

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Date: ……………………………….

To my beloved parents, family and friends

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ABSTRAK

Mencapai kualiti kimpalan yang baik untuk tempat kimpalan rintangan ketebalan tidak sama rata keluli lembaran logam semakin menjadi satu cabaran yang besar terutamanya dalam industri kereta. Secara amnya, percubaan dan kaedah kesilapan berdasarkan pengetahuan dan pengalaman pengimpal telah digunakan secara meluas oleh industri untuk pemilihan parameter kawalan kimpalan optimum untuk mencapai kimpalan yang berkualiti. Cubaan dibuat itu untuk mencari sistematik pemilihan parameter optimum dengan menggunakan data empirikal kaedah pemodelan statistik. Dalam kajian ini, kekuatan pada ujian tegangan ricih lima ketebalan yang berbeza, 0.5mm, 0.8mm, 1.0mm, 1.2mm dan 1.5mm keluli tergalvani lembaran logam JIS G3302 SGCC telah disiasat dengan menggunakan tempat kimpalan rintangan. Kaedah Permukaan Sambutan sebagai sebahagian daripada Rekabentuk Eksperimen telah diterima dengan empat parameter kimpalan semasa, kuasa elektrod, masa kimpalan dan ketebalan di lima peringkat dan model matematik telah dibangunkan. Dua yang tidak sama rata ketebalan plat keluli telah dikimpal bersama-sama di bawah julat 13-23 kA kimpalan semasa, 1,2-3,6 kN kuasa induk dan 5 - 25 kitaran masa yang digunakan untuk menjalankan eksperimen. Cerun tempat kimpalan rintangan ditetapkan 00 darjah dan masa memerah jumlah untuk kimpalan yang ditetapkan malar pada 80msand masa memegang di 50ms telah disimpan berterusan. Analisis varians teknik (ANOVA) telah digunakan untuk menyemak kecukupan model maju dan F-ujian telah digunakan untuk menentukan parameter yang paling penting yang mempengaruhi parameter kimpalan spot. Hasil kajian menunjukkan, semasa kimpalan memainkan peranan penting dalam menentukan kekuatan tegangan maksimum.

ABSTRACT

Achieving good weld quality for resistance spot welding of unequal thickness steel sheet metal is increasingly becoming a major challenge especially in automobile industries. Generally the 'trial and error' method based on the knowledge and experience of the welder has been widely adopted by the industry for the selection the optimum weld control parameters in order to achieve good quality welds. An attempt was made hence to systematically find the optimum parameter selection by applying empirical data based statistical modelling methods. In this research, the strength on the tensile-shear testing of five different thicknesses; 0.5mm, 0.8mm, 1.0mm, 1.2mm and 1.5mm of galvanized steel sheet metal JIS G3302 SGCC was investigated by using resistance spot welding. Response Surface Methodology as a part of Design of Experiment was adopted with four parameters; weld current, electrode force, weld time and thickness at five levels to develop mathematical models. Two unequal thickness steel plates were welded together under the range of 13-23 kA weld current, 1.2 - 3.6 kN of holding force and 5 – 25 cycles of time used to conduct the experiment. The slope of the resistance spot welding is set to 00 degree and the total squeeze time for the welding fixed constant at 80msand the hold time at 50ms were kept constant. Analysis of variance (ANOVA) technique was used to check the adequacy of the model developed and F-test has been used for determining the most significant parameters affecting the spot weld parameters. The results showed, the weld current plays a major role in determining the maximum tensile strength.

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LIST OF ABBREVIATIONS

ASTM	=	American Society of Testing and Material
AWS	=	American Welding Society
RSM	=	Response Surface Methodology
DOE	=	Design of Experiment
DOM	=	Design of Matrix
HAZ	=	Heat Affected Zone

LIST OF SYMBOLS

I	=	Current (in Ampere)
Σ	=	Strain Stress
K	=	Heat losses Factor
R	=	Resistance (in Ohm)
H	=	Heat generated (Watt per second)
MTS	=	Maximum Tensile Strength

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CHAPTER 1

INTRODUCTION

1.1 Background

Welding and joining have becoming more essential for the manufacturing industries and also for the structural fabrication, which may vary very large structures such as big ships and bridges, to very complex structures such as air craft engines or miniature components for micro-electronic application. (Norrish, 2006).

While these industries involve welding large components or structures, welding of thin strips, foils, wire and components are also widely used. Furthermore, these welding techniques are widely used in metal surfacing by welding processes where it is applies to several components in various industries for improving wear and corrosion resistance.

Welding processes, with modifications of operating conditions are also can be used to cut materials such as gas torch, metal arc, plasma arc and electron beam. In addition, welding processes can be classified into two categories:

i. Fusion Welding
ii. Solid state or non-fusion welding

i. Fusion Welding

In fusion welding, actual melting of the metal is involved in forming the bond. Examples are gas welding and arc welding processes.

ii. Solid state or non-fusion welding.

In solid state welding, heat energy and pressure is applied to the work pieces to be joined and bonding occurs primarily due to diffusion of atoms and intimate contact of clean surfaces. No melting process is involved. Examples are cold welding, diffusion bonding and friction welding (Srinivasan, 2008).

As early 19 century Elihu Thompson originated resistance spot welding (RSW) and he also stated that resistance spot welding follows the basic principles as follows;

"Resistance spot welding requires a transformer with the primary is and secondary is connected to its own specified cables. Both of cables which ends should be connected tightly by using clamps that will also hold the specimen of metals which will be welded together to hold firmly. Heavy current will pass through the joints and create such a huge heat to melt those metals to be combined as one". (COMPTON, 1939)

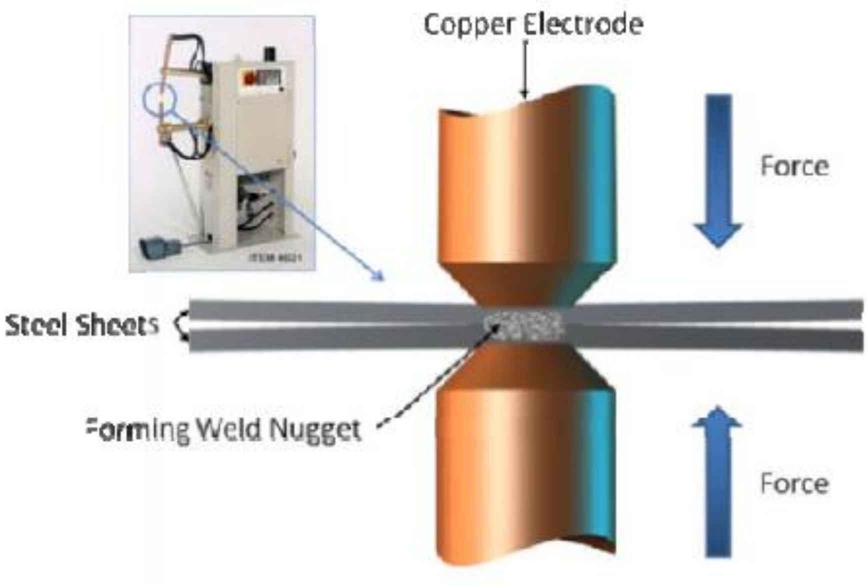

Figure 1-1 Resistance Spot Welding

Source: (N. Athi, S.R. Wylie, J.D Cullen, A.I. Al-Sharma, 2009)

For past several decades, Figure 1.1 resistance spot welding process has been widely used in fabricating sheet metals. Resistance spot welding is also inexpensive and effective way to join two metals. It is a process where metal surfaces are joined together by going through heat that is obtained due the resistance of electric current flow. These spot welds can be operate completely automated. There are three main stages involves in the resistance spot weld; the foremost is the squeeze time, followed by weld time and hold time.

Furthermore, this process are highly demanding in the automobile manufacturing industry whereby most common application is to weld the sheet metal to form a car. This process helps the automobile industry in achieving higher strength and also the productivity in manufacturing and repair. There is estimation that an ordinary car may contain 3000 to 5000 resistance spot welds, the common thicknesses will be in a range about 3mm (N. Athi, S.R. Wylie, J.D Cullen, A.I. Al-Sharma, 2009)]. It is must to evaluate the strength of those welded thin sheet metals in dynamic loading conditions to determine the optimum welding condition to help cutting down the cost, time and also materials. By determining the optimum welding condition may enhance the safety features in the automotive industry.

1.2 Problem Statement

In Automotive industry, resistance spot welding is commonly used to combine two pieces of sheet metals. Almost 3000-5000 spot welds are made in producing a car and usually the range of the thicknesses is around 0.5mm to 3mm. Therefore, it is very important to estimate the maximum strength of the material. In addition, failure in spot welded joining parts is because of unsuitable parameters setup. This experiment will deal with the possible parameters setup to come up with a new analysis, modeling and also to find the possible reason for the failure.

1.3 Objectives

1. To investigate and study the relationship between the process variables and mechanical response during resistance spot welding of unequal thickness steel sheets to develop mathematical models.

2. To predict, compare the develop model for optimization of mechanical responses.

1.4 Scope

1. To study, understand the theory and controlling of mechanical response of resistance spot dissimilar welds.

2. To apply design of experiment methodologies to develop mathematical models for prediction of responses and optimization.

CHAPTER 2

LITERATURE REVIEW

2.1 An Overview of Resistance Spot Welding

The resistance welding processes are commonly classified as pressure welding processes although they involve in a fusion welding at the interface of material being joined. Resistance spot, seam and projection welding rely on a similar mechanism. The specimen will be clamped in a certain force in between two electrodes and a high current is applied. Resistance heating at the contact surfaces causes local melting and fusion. A huge current is supplied for a certain duration (in micro seconds) and pressure is applied to the electrodes before the application of current and for a short time has ceased the flow.

Accurate control of current amplitude, pressure and weld cycle time is required to ensure the consistence in the weld quality. In some cases, variation may occur due to the changes in the contact resistance of the materials, electrode wear, magnetic losses or shunting of the current through previously formed spots. (Norrish, 2006).

Features of the basic resistance welding process include:

i. The process of resistance spot welding needs a basic equipment.
ii. The system used can be manipulated manually and automated.
iii. The weldmend is strong enough for relatively long runs of production.

The major applications of the process have been in the joining of sheet steel in the automotive industries. (S.H. Lin, J. Pan, S.R. Wu, T. Tyan, P. Wung, 2002)

2.2 Formal Welding Procedure Control

2.2.1 Selection of welding process

The process can be choose according to the material which will be used, the thicknesses and also the welding position. In most cases certain processes will meet the fundamental requirement of the application and the end choice is depends on the practical consideration (availability of equipment and operators). The choice of process will determine the number of control parameters which need to be considered and the nature of the control relationships. Computer software designed to simplify welding procedure selection.

2.2.2 Determine of welding parameters

The welding parameters include all the variables which need to be specified in order to ensure repeatable performance. This may involve the joint design, cleaning and edge preparation n preheating and post weld treatment as well as the process control parameters such as speed, voltage and current.

2.2.3 Assessment of joint performance

In order to test whether the procedure will produce the required joint characteristic, it will be necessary to carry out mechanical and non-destructive examination of sample welds which are made with the specified welding parameters (Norrish, 2006).

2.3 Resistance Welding Description

As stated earlier, in resistance spot welding heat generated through the electric resistance offered at the joint to a high current and sufficient pressure is also applied during the welding process. The amount of heat generated can be calculated from the formula:

$$H = I^2 R T$$

H = heat generated (J) joules

I = Current (A) Amperes

R = Resistance (Ohm)

T = Time (s) second

(N. Athi, S.R. Wylie, J.D Cullen, A.I. Al-Sharma, 2009)

The typical spot welding unit consists essential of transformer with a suitable switching circuit. The secondary transformer is connected to the both electrodes. The bottom electrode is fixed and the upper electrode is movable by using pressure. The upper electrode presses the sheet metal with the preset pressure at the appropriate time. The pressure is exerted through a system of springs or cams or hydraulic or pneumatic arms. There is a timing device attached to the machine. The welding cycle consists of four stages:

1. Approach stage
2. Welding stage
3. Forging stage
4. Pause

Figure 2.1 shows the relationship between force, current and time during a weld cycle. During the first stage, the force is slowly increased. In the second stage, current is applied for a specified duration. The force may slightly decrease due to the metal becoming softer and reaching the fusion point. After this, the current is shut off and additional force is applied. This is the third, forging stage. The pressure is held till the metal is cooled. Then the force is removed. There is a pause period before the next stage is started.

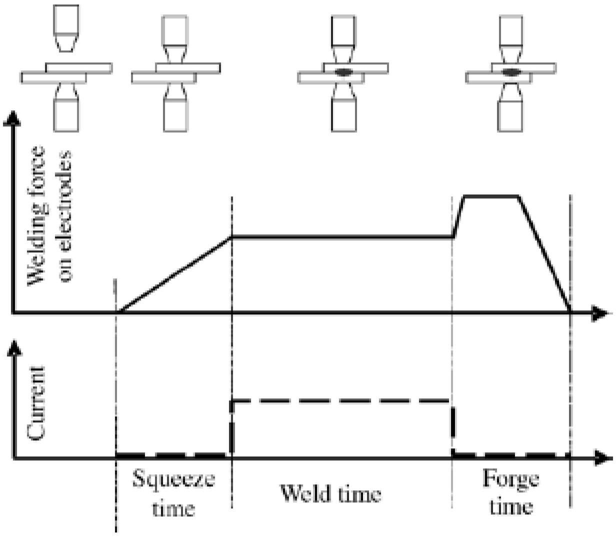

Figure2.1 Resistance Weld Cycle

Source: (A.M Pereira, J.A.M. Ferreira, F.V. Antunes, P.J. Bartolo, 2010)